DARK-FLOOR CRATERS: GALILEO CONSTRAINTS ON A GANYMEDE REGOLITH COMPONENT.

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Small (kilometer-scale), fresh-appearing impact craters with low-albedo floor deposits are conspicuous in high-resolution (100 m/pixel) Galileo images of Ganymede. Larger analogs (typically ten or more kilometers in size) have previously been documented [1,2] from Voyager images obtained at lower spatial resolution (1 km/pixel). Dark-floor craters are widely distributed over both dark (ancient cratered) terrain and bright (grooved) terrain. Voyager studies [1,2] showed that dark floor deposits have among the lowest albedos of any features on Ganymede. Two hypotheses for the origin of dark floor deposits are that they are concentrated deposits of dark impactor material[2] or that they represent impact melt from which the volatile (icy) constituents were lost due to vaporization[1]. In either case, if Ganymede regolith is considered to be a mixture of bright ice particles and a widespread low-albedo component, then the dark floor materials may provide the best available model for at least one dark contaminant. Because dark-floor deposits may themselves be multi-component mixtures, it is important to fully characterize their variability in albedo and color.

Our objectives in this study are 1) to measure albedos of dark-floor deposits in small craters from high-resolution Galileo images and compare them to analogous dark floor deposits in larger dark-floor craters, 2) to measure the spectral properties of dark floor materials at Galileo SSI wavelengths and compare to those of other Ganymede terrains.

SEARCH FOR A LOWER ALBEDO

Crater floor deposits with the lowest albedoes probably represent the purest exposures of a dark regolith end-member. For this reason, Schenk and McKinnon[2] reported estimates of normal albedos for only the darkest features visible in 31 globally distributed dark-floor craters ranging in diameter from 3.6 to 43.9 km. To obtain their data, they used Voyager CLR-filter (0.48um) images and a Ganymede dark terrain photometric model . A factor of 1.18, estimated from the average global telescopic spectrum of Ganymede[8], is needed to rescale their Voyager CLR filter albedos for comparison to Galileo CLR filter measurements we report below. So scaled, their darkest-detectable albedos range from 0.31 down to 0.12 with a mean of 0.22±0.05. As they noted, even the darkest crater deposits in this range are more than a factor of two too bright to represent pure deposits of candidate dark C- or D- type asteroid material.

Because most dark-floor deposits occur near the limit of Voyager spatial resolution, it is possible that darker crater floor deposits might be resolvable in high-resolution Galileo images. Galileo images (frames 3497589.39-3497589.78) of Uruk Sulcus obtained at low phase (12°) and high-resolution (75 m/pixel) are well-suited for measuring the albedos of dark-floor deposits in small craters. We measured reflectances (radiance factors) of dark floor deposits in 55 craters sized 1.5 km and larger from radiometrically corrected Galileo CLR filter (0.56um) images. Normal albedos of the dark floor deposits were estimated from these data by applying Hapke's [3,4,5] photometric equation and orresponding model parameters for Ganymede average dark terrain[6]. The resulting estimates of normal albedos for 7654 samples range from 0.12 to 0.32 with a mean of 0.25±0.04 and compare well with Voyager results. The fact that our lowest albedos are the same as those from Voyager results obtained at many other locations and at lower spatial resolution suggests that the darkest examples of crater floor deposits are a relatively widespread fundamental material on Ganymede’s surface.

GALILEO COLOR : AN EXAMPLE

During its second orbit, Galileo obtained a high resolution (131 m/pixel) four-color image sequence (frames 3599441.45-3599442.22) showing a prominent dark-floored crater in Uruk Sulcus. The SSI VLT (0.41um), GRN(0.56um), NIR (0.76um) and 1MC (0.99um) frames were assembled into color ratio images, however, image compression artifacts prohibit the accurate measurement of crater features that are small enough to represent the darkest floor deposits. We were able to extract an integral relative spectrum (normalized to the GRN filter reflectance) of the whole dark floor deposit. We also produced a GRN-filter albedo image using the approach described earlier and obtained an estimate of the mean normal albedo of the dark floor material. In Table 1, our relative spectrum of the dark floor has been scaled to spectral normal albedo using the mean GRN-filter normal albedo (0.21±0.04).

A whole-disk multispectral view of Ganymede, centered on 8ºS, 155ºW (lat,lon) and at 30º phase, was acquired by Galileo on its first orbit (frames 3496320.00-3496322.00). Following the approach above, we used these images to obtain average spectral normal albedos for all visible (non-polar) examples of dark (ancient cratered) and bright (grooved) terrain. All measurements were restricted to latitudes less than 40º to exclude Ganymede's polar frost. To reduce errors caused by inaccuracy of our photometric models at extreme photometric geometries, we excluded features at incidence angles greater than 75º and emission angles greater than 80º. Note that a photometric model for average bright terrain[6] was applied to extrapolate bright terrain radiance factors to corresponding estimates of normal albedo.

We also measured the whole-disk brightness of Ganymede from each of the color frames and provide an SSI whole-disk spectrum relative to the GRN filter brightness in Table 2. For comparison, we have convolved Ganymede's earthbased telescopic spectrum[8] to SSI bandpasses and in the last column of Table 2 provide scale factors which have been applied to the data of Table 1 to bring the SSI colors into agreement with earthbased observations.

On average relative colors of the broad terrain classes in Table 1 are statistically similar. Table 1 yields a VLT/GRN ratio for the dark floor of 0.71±0.05 which is not distinguishable from VLT/GRN = 0.72±0.03 for average bright terrain, but is slightly larger than for average dark terrain (VLT/GRN=0.68±0.02). The terrains differ most significantly in their 1MC/NIR ratios: For dark floor material 1MC/NIR = 1.12±0.06 is larger than for any terrain on Ganymede. The 1MC/NIR ratio for average dark terrain (1.00±0.04) is less than for dark floor material but greater than that for bright terrain (0.98±0.03).

The average albedo of our dark floor deposit is too large to be representative of the the darkest examples of crater floor material. However, if all of the terrain examples in Table 1 share only a single dark compositional end-member and the same bright end-member, then some mixture of the dark floor material with average bright terrain materials should yield the spectrum and albedo of average dark terrain. The last column in Table 1 shows that a simple areal mixture of 55% dark floor material with 45% average bright terrain material predicts the spectral normal albedo of average dark terrain materials to within an RMS error of under 3%.

Denk et al.[9] report specific examples of dark terrains whose relative colors differ so much from those of the dark floor deposit that a second dark end-member is proposed to exist. In this regard, Schenk and McKinnon[2] found significant variations in Voyager ORA/VLT (0.59um/0.41um) color ratios among dark crater floor deposits from a collection of different examples. While our Galileo VLT/GRN ratio from Table 1 is in good agreement with typical Voyager examples, additional Galileo multispectral coverage of dark-floor deposits will be needed to define their range of spectral properties and to more fully test the extent to which they may be used as spectral end-members to explain compositional diversity among Ganymede's terrains

SUMMARY

The uniformity of the lowest albedos observed in dark-floor deposits over many spatial scales and at many locations on Ganymede suggests that the darkest floor deposits are a widespread fundamental component of Ganymede soils. This hypothesis is supported by the fact that a simple spectral mixing model of average bright terrain with dark floor material predicts reasonably the color and albedo of broadly classed average dark terrain. It is important to note, however, that the dark floor spectrum used in this preliminary study was obtained from a single crater and additional measurements will be needed to characterize the spectral range of the darkest deposits on Ganymede.

TABLE 1: SPECTRAL NORMAL ALBEDOS OF GANYMEDE TERRAINS

λ (um)	CRATER DARK FLOOR	AVERAGE BRIGHT TERRAIN	AVERAGE DARK TERRAIN	AREAL MIX[a]
0.41	0.15±0.03	0.42±0.04	0.26±0.05	0.27
0.56	0.21±0.04	0.58±0.05	0.38±0.06	0.38
0.76	0.25±0.05	0.61±0.05	0.42±0.07	0.42
0.99	0.28±0.06	0.60±0.05	0.42±0.07	0.43

[a] Areal mixture of 55% Dark Floor and 45% Average Bright terrain

TABLE 2: WHOLE-DISK SSI SPECTRUM OF GANYMEDE (RELATIVE TO SSI GRN FILTER)

λ (um)	SSI SPECTRUM	CONVOLVED TELESCOPIC SPECTRUM	SCALE FACTOR
0.41 (VLT)	0.831	0.724	0.871
0.56 (GRN)	1.000	1.000	1.000
0.67 (RED)	1.043	1.055	1.012
0.76 (NIR)	1.091	1.059	0.971
0.89 (MT2)	1.086	1.048	0.965
0.99 (1MC)	1.077	1.029	0.955

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